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EG&G
ENERGY MEASUREMENTS GROUP

THE
**REMOTE
SENSING
LABORATORY**
OF THE UNITED STATES
DEPARTMENT OF ENERGY

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AERIAL RADIOLOGICAL SURVEYS OF

ROCKWELL INTERNATIONAL FACILITIES

CANOGA PARK, CALIFORNIA   DATES OF SURVEYS: JUNE AND JULY 1978

NOTICE

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J.E. Jobst
Project Scientist

APPROVED FOR PUBLICATION

T P Stuart

T. P. Stuart, Manager
Remote Sensing Sciences Department

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G P Stobie

G. P. Stobie
Classification Officer

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ABSTRACT

Aerial radiological surveys were conducted over two facilities operated by the Energy Systems Group, a Division of Rockwell International. The first survey, conducted on 26-27 June 1978 at an altitude of 46 m, was over the Headquarters Facility in urban Canoga Park, California. The second, on 29-30 June and 5-8 July 1978, was flown at 61 m altitude over the Santa Susana Field Laboratories in the Santa Susana Mountains, about 15 km west-northwest of the Headquarters.

Twenty sodium iodide detectors were mounted on a helicopter. Enhanced gamma exposure rate levels were observed during both surveys; these levels could be attributed to industrial operations at the survey sites.

These surveys were authorized by the United States Nuclear Regulatory Commission (NRC) and conducted by the U.S. Department of Energy (DOE) Remote Sensing Laboratory, which is operated for DOE by EG&G in Las Vegas, Nevada.

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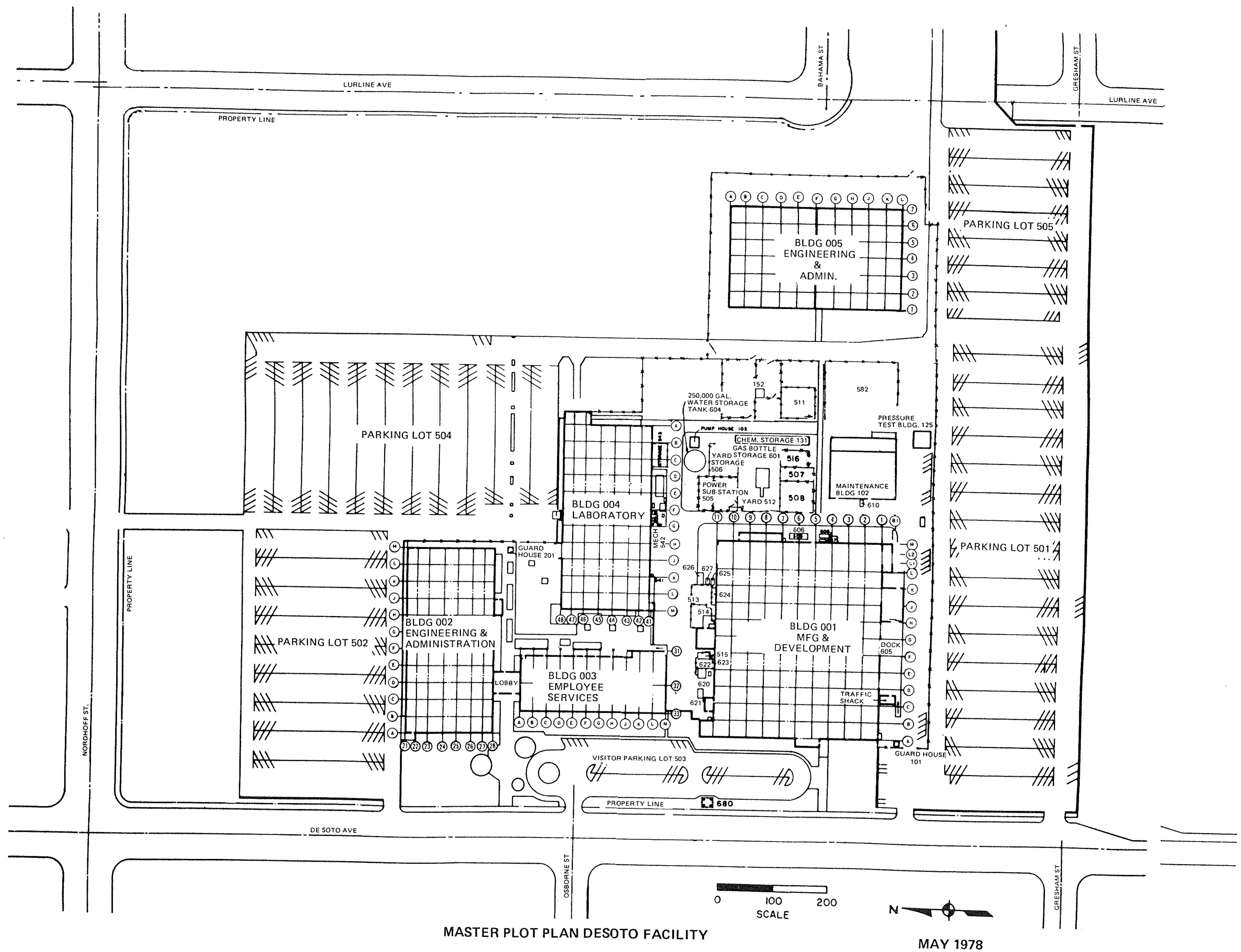


Figure 1. *PLOT PLAN OF CANOGA PARK HEADQUARTERS*

1.0 INTRODUCTION

The United States Department of Energy (DOE) maintains the Remote Sensing Laboratory in Las Vegas, Nevada. This facility is operated for DOE by the Energy Measurements Group of EG&G. Activities at the Laboratory are part of the Aerial Measuring Systems program (AMS). Since its inception in 1958, the AMS program has included radiological surveys of nuclear power plants, processing and manufacturing plants employing nuclear materials, and research laboratories. AMS aircraft have been deployed to nuclear accident sites and in searches for lost radioisotopes, in addition to routine use during launch operations for Apollo, Viking, and other space vehicles which contained radioisotope thermal generators. Most of the AMS equipment and personnel were deployed in the successful search for fragments of Cosmos 954, the Russian nuclear-powered satellite which crashed in the Northwest Territories of Canada in January 1978. AMS aircraft also have mapping cameras and multispectral camera arrays for aerial photography; multispectral scanners for ultraviolet, visible, and infrared imagery; a broad array of meteorological sensors; and air sampling systems for particulate and whole gas measurements.

The AMS program is maintained and operated for DOE by EG&G. At the request of federal or state agencies, AMS is deployed for various aerial survey operations.[1] The surveys of Rockwell facilities reported here were commissioned by the U.S. Nuclear Regulatory Commission.

2.0 SITE DESCRIPTION

This report presents the results of two surveys; the sites for both are operated by the Energy Systems Group, a Division of Rockwell International, Canoga Park, California 91304. The first site is an engineering, fabrication, and assembly plant in urban Canoga Park. The master plot plan, shown in Figure 1, indicates the major facilities at the DeSoto plant. The primary subject of the survey was a rectangular plot approximately 530 x 380 meters (m). This plot is bounded on the south by a fence line parallel to a nonexistent segment of Gresham Street, on the west by DeSoto Avenue, on the north by Nordhoff Street, and on the east by Lurline Avenue.

This plant is in a highly urbanized area, surrounded on the south and west by apartments, single family homes, and a large trailer park. North and east of the plant are business and industrial facilities. The site is quite level, with many business and residential structures 10-15 m tall.

The second site, 15 km west-northwest of the DeSoto Facility, is an engineering and research facility called the Santa Susana Field Laboratories or the Energy Technology Engineering Center (ETEC). The subject of the survey is an irregularly shaped plot, 1400 m long by 650 m wide, on Burro Flats in the Simi Hills. In Figure 2 the facilities of interest are enclosed by a dashed line. Rockwell International owns the land; however, the U.S. Department of Energy owns the facilities and has an option on the land.

This site is on a rugged ridge overlooking the Simi Valley to the north. Access is restricted to authorized personnel. The closest private residence is perhaps 2 km from the survey area, along the mountainous road leading to it. In addition to tall buildings and rock outcroppings, the site had an industrial crane 60 m tall and many power line obstructions.

3.0 SURVEY PLAN

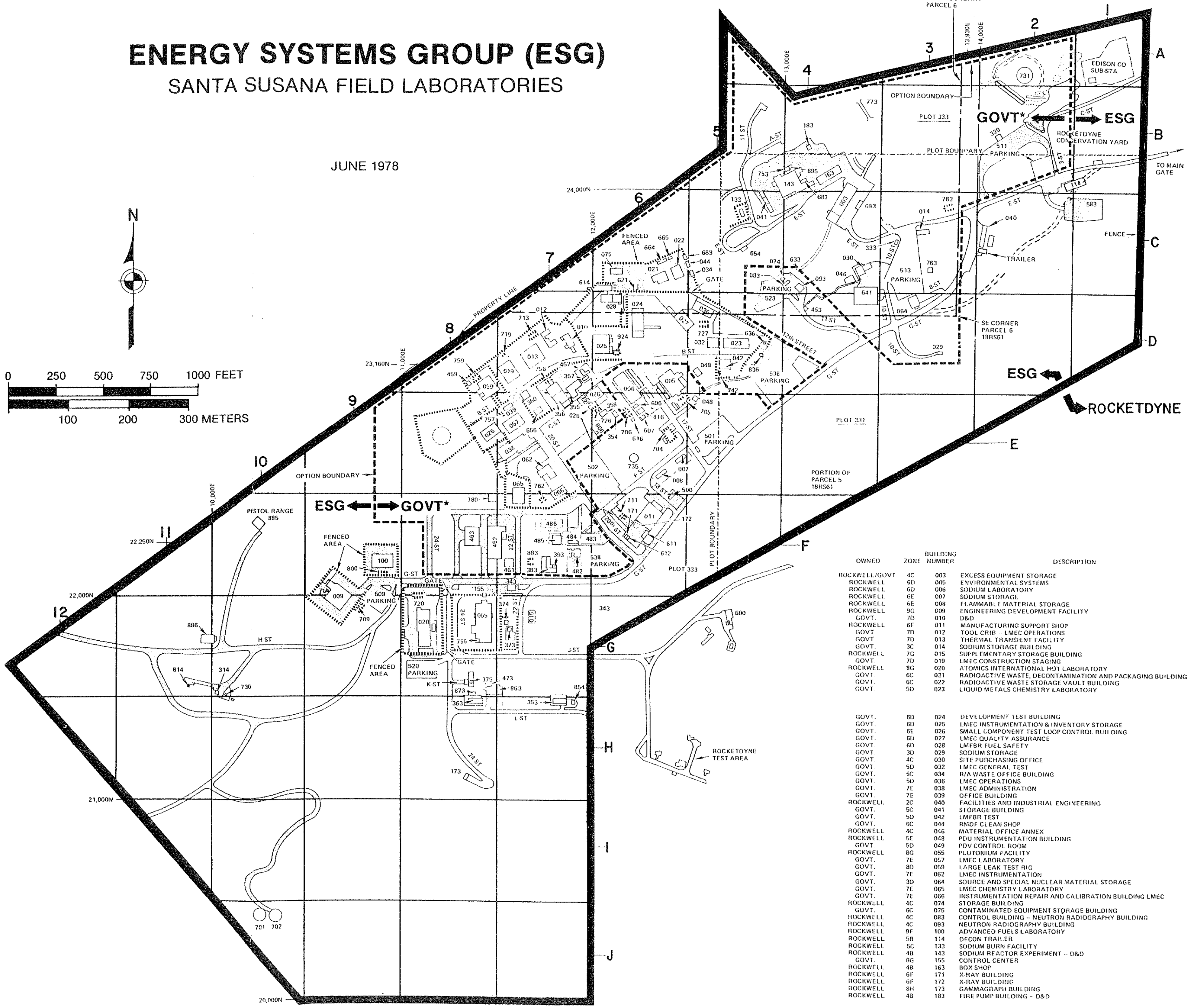
To minimize commuting time for both of these surveys, an operations base was established on Rockwell property. At the DeSoto plant a temporary helicopter pad was established between Storage Yard 582 and Engineering and Administration Building 005, just north of the Parking Lot 505 fence (Figure 1). The heliport on Engineering and Administration Building 002 was not used because it lacked appropriate support equipment (power, fuel, etc.).

A recent aerial photograph of the facility was used as a base map (scale 4800:1). Survey lines were laid out with 46 m (150 ft) spacing. As in all aerial surveys, the flight pattern was designed to go well beyond the target site; coverage in this case is 800 - 1200 m beyond the boundaries indicated in Section 2.0. The lines actually flown are superimposed on an aerial photo map in Figure 3. The lines were flown at an approximate radar altitude of 46 m (150 ft) with the aid of a steering indicator, which is described in the Appendix. A total of 47 lines were required.

ENERGY SYSTEMS GROUP (ESG)

SANTA SUSANA FIELD LABORATORIES

JUNE 1978



OWNED	ZONE	BUILDING NUMBER	DESCRIPTION
ROCKWELL/GOVT	4C	003	EXCESS EQUIPMENT STORAGE
ROCKWELL	6D	005	ENVIRONMENTAL SYSTEMS
ROCKWELL	6D	006	SODIUM LABORATORY
ROCKWELL	6E	007	SODIUM STORAGE
ROCKWELL	6E	008	FLAMMABLE MATERIAL STORAGE
ROCKWELL	9G	009	ENGINEERING DEVELOPMENT FACILITY
GOVT.	7D	010	D&D
ROCKWELL	6F	011	MANUFACTURING SUPPORT SHOP
GOVT.	7D	012	TOOL CRIB – LMEC OPERATIONS
GOVT.	7D	013	THERMAL TRANSIENT FACILITY
GOVT.	3C	014	SODIUM STORAGE BUILDING
ROCKWELL	7G	015	SUPPLEMENTARY STORAGE BUILDING
GOVT.	7D	019	LMEC CONSTRUCTION STAGING
ROCKWELL	8G	020	ATOMICS INTERNATIONAL HOT LABORATORY
GOVT.	6C	021	RADIOACTIVE WASTE, DECONTAMINATION AND PACKAGING BUILDING
GOVT.	6C	022	RADIOACTIVE WASTE STORAGE VAULT BUILDING
GOVT.	5D	023	LIQUID METALS CHEMISTRY LABORATORY
GOVT.	6D	024	DEVELOPMENT TEST BUILDING
GOVT.	6D	025	LMEC INSTRUMENTATION & INVENTORY STORAGE
GOVT.	6E	026	SMALL COMPONENT TEST LOOP CONTROL BUILDING
GOVT.	6D	027	LMEC QUALITY ASSURANCE
GOVT.	6D	028	LMFBR FUEL SAFETY
GOVT.	3D	029	SODIUM STORAGE
GOVT.	4C	030	SITE PURCHASING OFFICE
GOVT.	5D	032	LMEC GENERAL TEST
GOVT.	5C	034	R/A WASTE OFFICE BUILDING
GOVT.	5D	036	LMEC OPERATIONS
GOVT.	7E	038	LMEC ADMINISTRATION
GOVT.	7E	039	OFFICE BUILDING
ROCKWELL	2C	040	FACILITIES AND INDUSTRIAL ENGINEERING
GOVT.	5C	041	STORAGE BUILDING
GOVT.	5D	042	LMFBR TEST
GOVT.	6C	044	RMDF CLEAN SHOP
ROCKWELL	4C	046	MATERIAL OFFICE ANNEX
ROCKWELL	5E	048	PDU INSTRUMENTATION BUILDING
GOVT.	5D	049	PDV CONTROL ROOM
ROCKWELL	8G	055	PLUTONIUM FACILITY
GOVT.	7E	057	LMEC LABORATORY
GOVT.	8D	059	LARGE LEAK TEST RIG
GOVT.	7E	062	LMEC INSTRUMENTATION
GOVT.	3D	064	SOURCE AND SPECIAL NUCLEAR MATERIAL STORAGE
GOVT.	7E	065	LMEC CHEMISTRY LABORATORY
GOVT.	7E	066	INSTRUMENTATION REPAIR AND CALIBRATION BUILDING LMEC
ROCKWELL	4C	074	STORAGE BUILDING
GOVT.	6C	075	CONTAMINATED EQUIPMENT STORAGE BUILDING
ROCKWELL	4C	083	CONTROL BUILDING – NEUTRON RADIOGRAPHY BUILDING
ROCKWELL	4C	093	NEUTRON RADIOGRAPHY BUILDING
ROCKWELL	9F	100	ADVANCED FUELS LABORATORY
ROCKWELL	5B	114	DECON TRAILER
ROCKWELL	5C	133	SODIUM BURN FACILITY
ROCKWELL	4B	143	SODIUM REACTOR EXPERIMENT – D&D
GOVT.	8G	155	CONTROL CENTER
ROCKWELL	4B	163	BOX SHOP
ROCKWELL	6F	171	X-RAY BUILDING
ROCKWELL	6F	172	X-RAY BUILDING
ROCKWELL	8H	173	GAMMAGRAPH BUILDING
ROCKWELL	4B	183	FIRE PUMP BUILDING – D&D

OWNED	ZONE	BUILDING NUMBER	DESCRIPTION
ROCKWELL	10G	314	LARGE LEAK INJECTOR DEVICE (LLID) TEST CONTROL BUILDING
GOVT.	2B	320	FUEL OIL CONTROL BUILDING
ROCKWELL	3C	333	TIME CLOCK BUILDING
ROCKWELL	7G	343	TIME CLOCK BUILDING
ROCKWELL	7H	353	RESEARCH AND DEVELOPMENT LABORATORY BUILDING
GOVT.	6E	354	CONTROL ELEMENT TEST STRUCTURE
GOVT.	7D	355	SCTI CONTROL BUILDING
GOVT.	7D	356	SODIUM COMPONENT TEST INSTALLATION
GOVT.	7D	357	LMEC PUMP BEARING TEST FACILITY CONTROL BUILDING
GOVT.	6E	358	SCTI SUPPORT BUILDING
GOVT.	7E	359	COMPRESSOR BUILDING
GOVT.	7E	360	CHEMICAL STORAGE BUILDING
ROCKWELL	8H	363	RESEARCH AND DEVELOPMENT LABORATORY BUILDING
ROCKWELL	7G	373	DEVELOPMENT TEST BUILDING
GOVT.	7G	374	TEST LOOP ENCLOSURE
ROCKWELL	8G	375	CONTROL SHELTER BUILDING
GOVT.	7F	383	LMEC CONSTRUCTION STAGING
ROCKWELL	4D	453	STG. NEUTRON RADIOGRAPHY STORAGE
GOVT.	7D	457	PUMP BEARING TEST STRUCTURE
GOVT.	8D	459	UNINTERRUPTIBLE POWER SUPPLY
GOVT.	7F	461	MOTOR GENERATOR BUILDING
GOVT.	8F	462	SODIUM PUMP TEST FACILITY
GOVT.	8F	463	CHCF
ROCKWELL	8G	473	HYDRAULIC TEST INSTRUMENTATION BUILDING
GOVT.	7F	482	GOVERNMENT PROJECT OFFICES
GOVT.	7F	483	LMEC OFFICE COMPLEX
GOVT.	7F	484	REST ROOM – TRAILER
GOVT.	7F	485	LMEC OFFICE COMPLEX
GOVT.	7F	486	LMEC OFFICE COMPLEX
GOVT.		487	LMEC OFFICE COMPLEX
GOVT.		488	REST ROOM TRAILER
ROCKWELL	6F	500	COMPRESSED GAS BOTTLE STORAGE DOCK
ROCKWELL	5E	501	PARKING LOT
ROCKWELL	7E	502	PARKING LOT
ROCKWELL	9G	509	PARKING LOT
ROCKWELL	2B	511	PARKING LOT
GOVT.	3C	513	PARKING LOT
ROCKWELL	8G	520	PARKING LOT
ROCKWELL	5C	523	PARKING LOT
ROCKWELL	5D	536	PARKING LOT
GOVT.	6F	538	PARKING LOT
ROCKWELL	7G	573	PARKING LOT
ROCKWELL	2B	583	CONSERVATION STORAGE YARD
ROCKWELL	5F	600	SEWAGE TREATMENT PLANT
ROCKWELL	6E	606	HYDROGEN RECOMBINER TEST
ROCKWELL	6F	611	PAINT SPRAY BOOTH
ROCKWELL	6F	612	STORAGE BUILDING
GOVT.	7C	614	DRAINAGE SUMP
ROCKWELL	6E	616	COOLING TOWER
GOVT.	6C	621	RADIOACTIVE ACCOUNTABLE WASTE STORAGE BUILDING
ROCKWELL	2B	623	GUARD POST NO. 1
GOVT.	8E	626	LMEC INVENTORY STORAGE
ROCKWELL	4C	633	REACTOR COOLING WATER PAD
GOVT.	5D	636	GUARD POST
GOVT.	4C	641	RECEIVING & STORAGE BUILDING
GOVT.	5C	654	INTERIM RADIOACTIVE WASTE – D&D
GOVT.	7E	656	SCTI COOLING TOWER
GOVT.	6C	664	LOW LEVEL RADIOACTIVE WASTE PROCESSING
GOVT.	6C	665	RMDF OXIDATION FACILITY
GOVT.	4C	683	ELECTRICAL SUBSTATION
GOVT.	6C	688	AUXILIARY SKID BUILDING
GOVT.	4C	693	ELECTRICAL SUBSTATION NO.1
GOVT.	4B	695	COLD TRAP VAULT (SRE) – D&D
ROCKWELL	10J	701	WATER TANK (DEER FLATS)
ROCKWELL	10J	702	WATER TANK (DEER FLATS)
GOVT.	6E	704	ELECTRICAL SUBSTATION
ROCKWELL	6E	705	ELECTRICAL SUBSTATION
ROCKWELL	6E	706	ELECTRICAL SUBSTATION
ROCKWELL	9G	709	ELECTRICAL SUBSTATION
ROCKWELL	6F	711	ELECTRICAL SUBSTATION
GOVT.	7D	713	ELECTRICAL SUBSTATION
GOVT.	7D	719	ELECTRICAL SUBSTATION
ROCKWELL	8G	720	ELECTRICAL SUBSTATION
GOVT.	7D	726	ELECTRICAL SUBSTATION
GOVT.	5D	727	ELECTRICAL SUBSTATION
ROCKWELL	10G	730	STORAGE SHED
GOVT.	2A	731	1.5M FUEL OIL STORAGE TANK
GOVT.	6E	735	86K FUEL OIL STORAGE DAY TANK
GOVT.	5D	742	ELECTRICAL SUBSTATION
GOVT.	4B	753	PRIMARY FILL TANK VAULT – D&D
ROCKWELL	8G	755	ELECTRICAL SUBSTATION
GOVT	7D	756	ELECTRICAL SUBSTATION
GOVT.	8E	757	ELECTRICAL SUBSTATION
GOVT.	8D	759	ELECTRICAL SUBSTATION
GOVT.	7F	762	ELECTRICAL SUBSTATION
GOVT.	3C	763	ELECTRICAL SUBSTATION
GOVT.	4B	773	DRAINAGE CONTROL DAM
GOVT.	8F	780	ELECTRICAL SUBSTATION
SCE	3C	783	ELECTRICAL SUBSTATION
ROCKWELL	9F	800	ELECTRICAL SUBSTATION
ROCKWELL	7E	805	TIME CLOCK BUILDING
ROCKWELL	11G	814	LARGE LEAK INJECTOR DEVICE
ROCKWELL	6E	816	RECOMBINER CANOPY
ROCKWELL	5D	836	TIME CLOCK BUILDING
GOVT	7H	854	TEST STRUCTURE
ROCKWELL	7H	863	HYDRAULIC TEST LOOP
ROCKWELL	8G	873	HYDRAULIC TEST LABORATORY
ROCKWELL	7F	883	ELECTRICAL SUBSTATION
ROCKWELL	10F	885	PISTOL RANGE
ROCKWELL	11G	886	SODIUM DISPOSAL FACILITY
GOVT.	6D	924	ELECTRICAL SUBSTATION

Figure 2. *PLOT PLAN OF SANTA SUSANA FACILITIES (ETEC)*

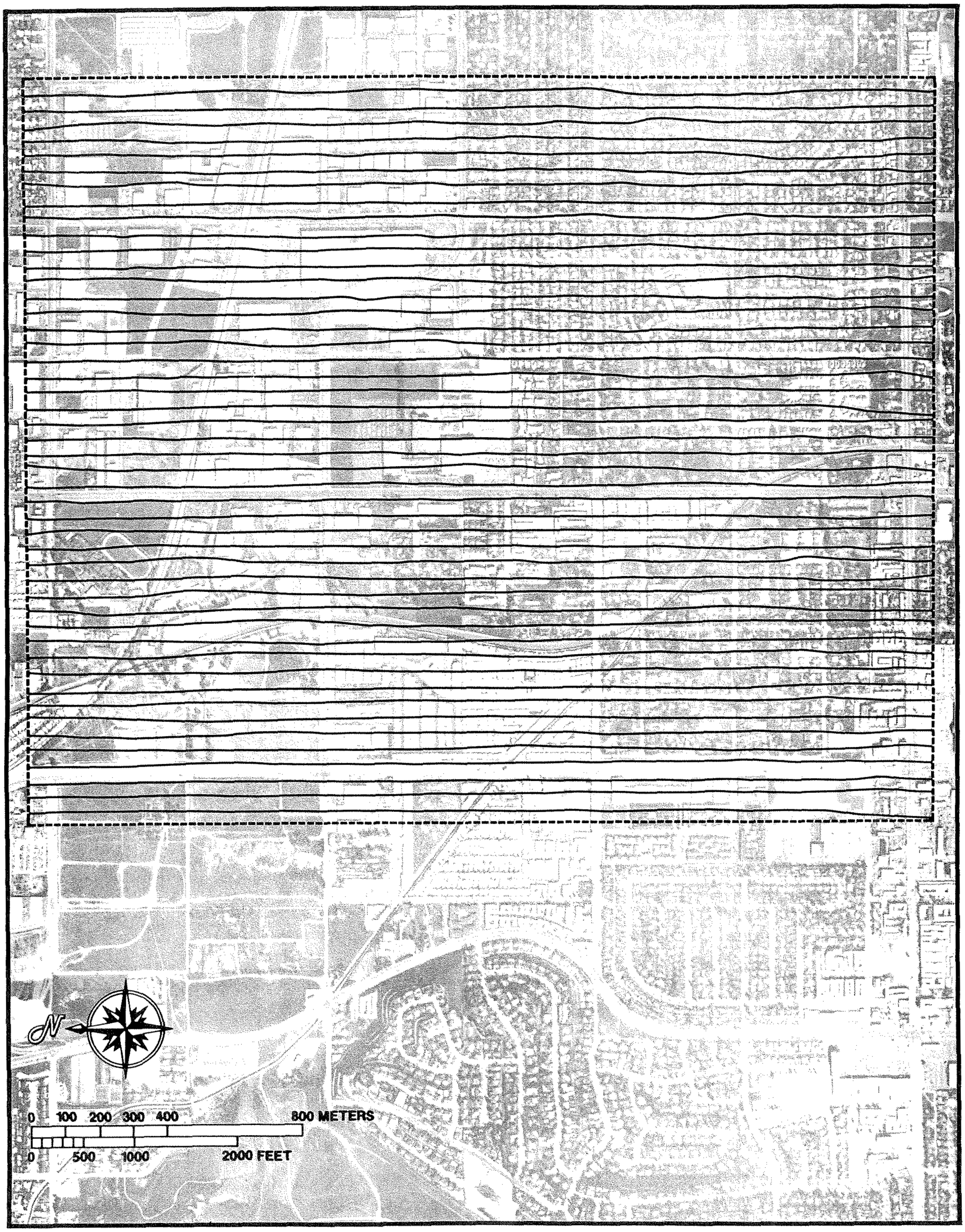


Figure 3. *FLIGHT LINE MAP FOR CANOGA PARK*

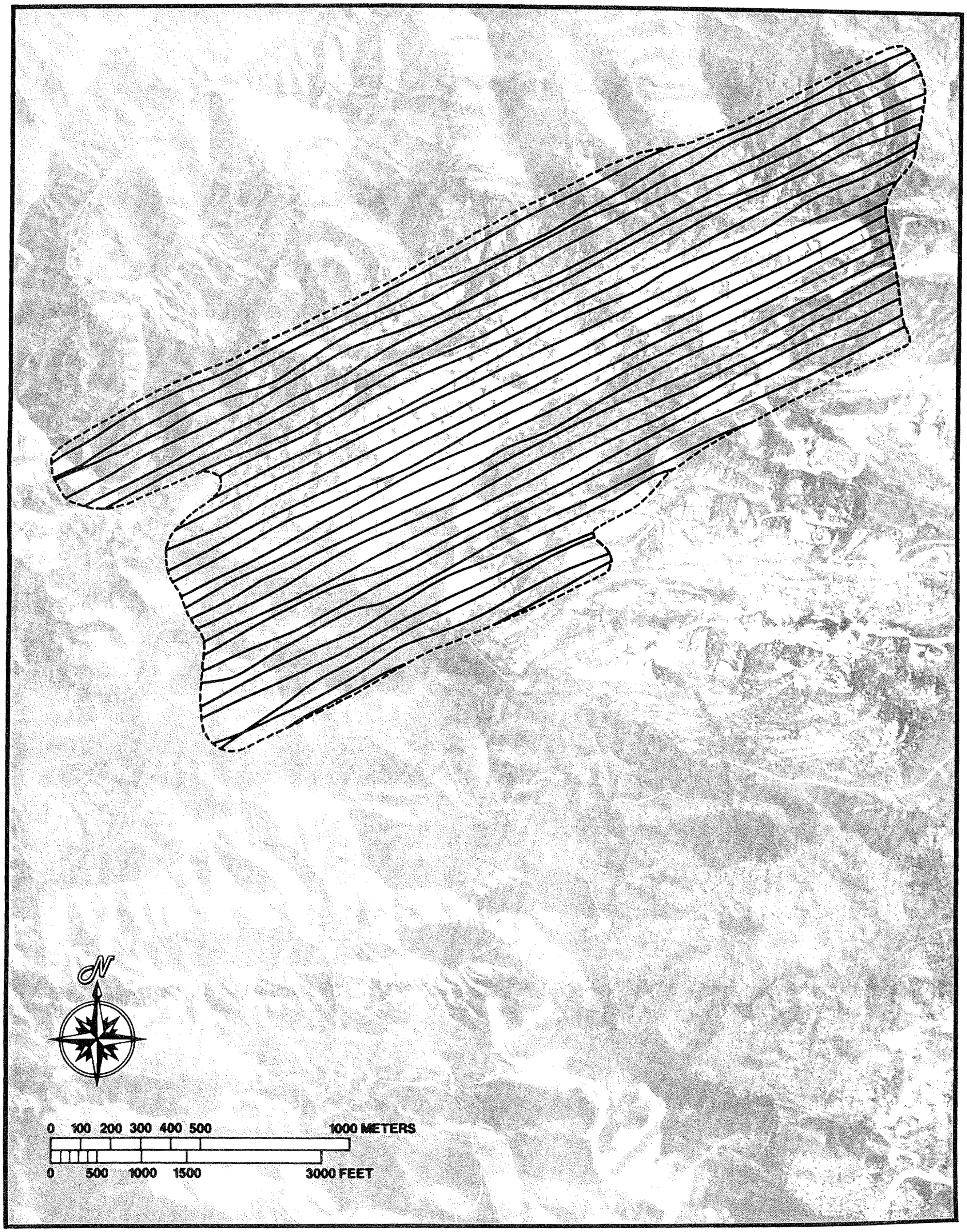


Figure 4. *FLIGHT LINE MAP FOR SANTA SUSANA*

In order to survey the Santa Susana facilities, the entire base of operations was transferred there. Lines were laid out on a recent photograph with the same spacing: 46 m (150 ft). In this case, because of the difficult flying conditions,the survey lines were flown at 61 m (200 ft) altitude. The lines actually flown are shown in Figure 4. Minimum coverage in this survey was at least 125 m beyond the targeted area; for most portions of the site, flight lines extend several hundred meters beyond the dashed line shown in Figure 2.

4.0 SURVEY EQUIPMENT

A Hughes H-500 helicopter was used for both surveys (Figure 5). This aircraft carried a crew of two and a lightweight version of the Radiation and Environmental Data Acquisition and Recorder system (REDAR). Two pods were mounted on the sides of the helicopter; each contained ten 12.7 cm diameter by 5.1 cm thick sodium iodide NaI(Tl) detectors.

Figure 5. *HUGHES H-500 SURVEY HELICOPTER*
The Hughes H-500 is an excellent aerial platform for small survey sites. Twenty NaI detectors are carried in two pods on the sides of the aircraft. The REDAR system is mounted in the rear half of the passenger compartment.

The preamplifier signal from each detector was calibrated with a ^{88}Y or ^{22}Na source. Normalized outputs of each detector were combined for each array in a 10-way summing amplifier. The outputs of each array were matched and combined in a 2-way summing amplifier. Finally, this signal was adjusted in the analog-to-digital converter (ADC) so that the calibration peak appeared in a preselected channel of the multichannel analyzer of the REDAR.

The REDAR system contains four memories for data storage. In the first the following are stored: gross count data, single channel data, position information, live time, radar altitude, and meteorological data from various transducers. The second and third memories are operated in a flip-flop mode to store gamma ray spectral information. Memories one and, alternately, either two or three, are stored every 3 seconds on a 9-track magnetic tape. The fourth memory is used solely for real-time analysis on board the aircraft. Data in the fourth memory is not stored on magnetic tape.

The REDAR system can continuously acquire and record specific data at indicated rates (Table 1).

Table 1. REDAR System Data Input

Parameter	Frequency (Seconds)
1. 305 channel pulse-height analyzer plus live time	3.0
2. 5 single-channel analyzers with adjustable upper and lower discriminators	0.2
3. Gross count channel (sums all counts)	0.1
4. Position measurement	1.0
5. Microwave Ranging System (MRS) distance measurements	1.0
6. Radar altimeter	1.0
7. Absolute pressure	1.0
8. Outside air temperature	1.0
9. Wind speed	1.0
10. Wind direction	1.0
11. Dew point	1.0
12. True air speed	1.0
13. On-top marker	As required (operator push-button)
14. System configuration	1.0
15. Time of day clock (HRS-MIN-SEC)	1.0

Outputs from each detector are summed before being processed by the multichannel or single channel analyzer. Windows are set on the single channel analyzers to monitor regions of the spectrum pertinent to isotopes of interest.

All of the foregoing data inputs, including the on-top marker, may be displayed by the electronic system operator for real-time monitoring. Digital data—such as count rates, meteorological information, or time of day—are displayed on one of several light-emitting diode (LED) readouts. Gamma ray spectral data may be examined on the oscilloscope as the data accumulate. At any point in time a spectrum may be frozen for critical examination without affecting the continuous acquisition and recording of data. A dual-pen strip chart recorder permits visual monitoring of the time variations in any two of the following: gross count, mathematical combinations of single channel windows, radar altimeter, absolute pressure, outside air temperature, dew point, or true air speed.

Data are permanently recorded on a 9-track Cipher Data Products digital recorder capable of recording continuously for five hours. All data are recorded directly from sensors as raw information. The five single channels can be set to monitor natural, cosmic, or man-made gamma-active nuclides by appropriate discriminator settings. Each single channel can be weighted, added to, or subtracted from other single channels. Appropriately weighted data can be plotted in real time on the dual strip chart recorder aboard the aircraft, with filtering times between 0.2 seconds and 16 seconds. Hence, when the operator is searching for a particular radionuclide, the single channels are set up to enhance the capability of detecting this source in real time.

The helicopter position was established with two systems: a Trisponder/202A microwave ranging system, and an AL-101 radio altimeter. The Trisponder master station, mounted in the helicopter, interrogated two remote tranceivers; these were mounted several kilometers from the survey area. By measuring the round trip propagation time between the master and remote stations, the master computed the distance to each. These distances were recorded on magnetic tape each second. In subsequent computer processing they were converted to position coordinates.

The radio altimeter aboard the helicopter similarly measured the time lag for the return of a pulsed signal and converted this to aircraft altitude. For these surveys, altitude was accurate to ± 2 m. These data were also recorded on magnetic tape so that any variations in gamma signal strength caused by altitude fluctuation could be accurately compensated.

The detectors and electronic systems which accumulate and record the data are described only briefly here. They are described in considerable detail in previous reports.[2,3]

Precise coverage of any survey site requires that a parallel array of survey lines be programmed. The altitude must be low and the lines closely spaced so that the probability of detection is high for radiation sources of interest. Both the altitude and spacing are determined by the photon energy of the radioisotopes which may be present. Because Rockwell operations at both sites involve low energy isotopes, such as ^{235}U, low altitudes and tight spacing were desirable.

It is also obvious that programmed survey lines must be accurately flown so that small sources are not lost in accidental gaps between lines. The Remote Sensing Laboratory recently developed a Steering Indicator Computer system to aid the helicopter pilot in flying an accurate course (Appendix).

5.0 DATA PROCESSING EQUIPMENT

Magnetic tapes from these surveys are processed with the Radiation and Environmental Data Analyzer and Computer system (REDAC). This is a computer analysis laboratory built into a 5-ton step van. The interior of the van is shown in Figure 6. The REDAC system consists primarily of two Cipher Data Products tape drives, a Data General NOVA 840 computer, two Calcomp plotters, and a Tektronix CRT display screen with a hard copier. The computer has a 32 k-word core memory and an additional 1.2×10^6 -word disc memory. An extensive series of software routines is available for data processing.

Gamma spectral windows can be selected for any portion of the spectrum between for example, 50 keV and 3 MeV. Weighted combinations of such windows can be summed or subtracted and the result plotted as a function of time or position. By the proper selection of windows and weighting

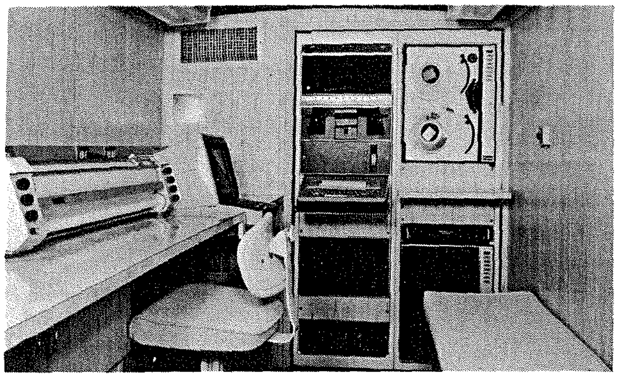


Figure 6. *MOBILE COMPUTER PROCESSING LABORATORY*
The heart of the REDAC system is a NOVA 840 minicomputer. In many surveys the REDAC van is located at the survey site, which makes possible immediate data processing.

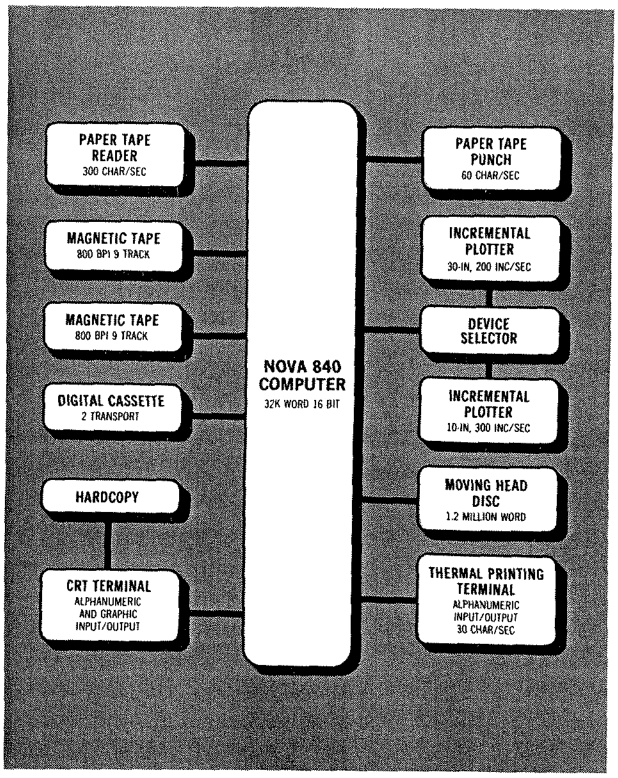


Figure 7. *BLOCK DIAGRAM OF REDAC SYSTEM*
This a block diagram of the Radiation and Environmental Data Analvzer and Computer system (REDAC).

factors, it is possible to extract the photopeak count rates for radioisotopes deposited on the terrain by human activity. Such isotopes disturb the natural pattern of soil radioactivity. These photopeak count rates can then be converted to isotope concentrations or exposure rates. Spectral data can be summed over any portion of a survey flight line. A block diagram of the REDAC system is shown in Figure 7.

6.0 DATA ANALYSIS

For both of these surveys data analysis has been directed to producing two specific results: (1) a gamma gross count isopleth map, and (2) gamma radiation spectra from the aerial data which accurately characterize the sites.

To produce a gross count isopleth, the REDAC is programmed to select gamma counts occurring within a 1 second time interval from an extremely wide energy interval (40 keV to 4.07 MeV). A conversion factor is applied to the difference between these counts and counts of non-terrestrial origin to obtain exposure rate at the 1 m level due to sources in the soil. The sum of this exposure rate and the cosmic ray exposure rate is plotted as a function of position over the site. For most surveys the non-terrestrial counts are measured by flying the aircraft at the survey altitude over a large water body convenient to the site. Background contributions are normally measured at least once each day and during each flight, if this is practical. Over water the detectors see background counts due to cosmic rays and minute sources within the materials of which the detectors, electronic systems, aircraft instruments, and the helicopter are made. Radon gas and the other radioactive gases or particulates suspended in the air contribute to both the land flights and the water flights. The cosmic ray contribution changes diurnally and with the seasons; radon and other gas contributions may change within a few hours.

Neither the Canoga Park nor Santa Susana sites are close to water bodies. Hence, the background was derived from measurements made the previous week during survey work in La Jolla, California. For this work the measured background was 834 counts per second (cps), which is equivalent to an exposure rate of 0.7 microroentgen per hour (μR/h). The 834-count background is subtracted from each 1-second gross count sum so that the result characterizes terrestrial sources only. Previous calibration work with this system at the survey altitude of 46 m (150 ft) indicates that 1130 counts per second (cps), from terrestrial sources only, is equivalent to an exposure rate of 1 μR/h at an altitude of 1 m.

As the final step, the REDAC system was programmed to convert the count rate of terrestrial origin to equivalent exposure rate, 3.5 μR/h were added for the cosmic radiation contribution, and the results were plotted as a function of position. The numerical value of the cosmic exposure rate was inferred from the data of Lindeken, et al.[4] The cosmic contribution is then added to the terrestrial to make the isopleth easier to compare with other field measurements.

On a scale determined by the aerial photo used as a base map for the survey, the REDAC system plotted total exposure rate (terrestrial plus cosmic) as a function of aircraft position. Rates were then letter-coded for the Canoga Park Facility (Table 2).

Only the maximum count and exposure rates are shown for each label. That is, the computer assigns the letter H to any count rate between 9081 and 9710 counts per second. The corresponding exposure rate for H obviously covers a range from 8.0 to 8.6 μR/h (terrestrial only).

To obtain the total exposure rate a cosmic ray component of 3.5 μR/h is added to the terrestrial, as previously indicated. Estimates of this cosmic component vary from 3.5 to 4.0 μR/h. No measurements of this contribution were made specifically for these surveys. Hence, the cosmic contribution must be inferred from the work of others. Lindeken, et al,[4] measured environmental radiation throughout the United States in 1971 with thermoluminescent dosimeters. They concluded that the cosmic exposure rate for San Diego and Santa Maria, California was 3.5 μR/h for their test period. Cosmic radiation levels change during the 11-year solar cycle; they also vary with altitude and latitude. The higher the altitude, the greater the cosmic component of the total exposure rate.

No accurate information on the variation of cosmic ray levels at these sites is available to the author. Hence, an estimated cosmic contribution of 3.5 μR/h was added to the measured terrestrial contribution in Table 2. This value could be low by a few 1/10's of μR/h. The procedure is followed so that the gross count isopleth can be more easily compared with other field measurements.

A similar set of levels was prepared for the Santa Susana survey. A considerably compressed scale was required because of the much broader range of exposure rates measured in the second survey. The results are shown in Table 3. As in the previous table 3.5 μR/h is added for the cosmic contribution and each letter represents a range of exposure rates; i.e., R indicates a level ranging from slightly above 116 to 142 μR/h. Because the survey altitude had been increased to 61 m (200 ft), the conversion factor is now 1024 counts per second per μR/h.

Table 2. Canoga Park Gamma Gross Count Rate and Exposure Rate

Letter Label	Maximum Count Rate (cps, in thousands)	Maximum Terrestrial (Exposure Rate(μR/h)	Total Exposure Rate (μR/h)
A	5.30	4.7	8.2
B	5.93	5.3	8.8
C	6.56	5.8	9.3
D	7.19	6.4	9.9
E	7.82	6.9	10.4
F	8.45	7.5	11.4
G	9.08	8.0	11.5
H	9.71	8.6	12.1
I	10.34	9.2	12.7
J	10.97	9.7	13.2
K	11.60	10.3	13.8
L	12.23	10.8	14.3
M	12.86	11.4	14.9
N	13.49	11.9	15.4
O	14.12	12.5	16.0
P	14.75	13.1	16.6

Table 3. Santa Susana Gamma Gross Count Rate and Exposure Rate			
Letter Label	Maximum Count Rate (cps, in thousands)	Maximum Terrestrial Exposure Rate (μR/h)	Total Exposure Rate (μR/h)
A	9.00	8.8	12.3
B	10.0	9.8	13.3
C	11.0	10.7	14.2
D	12.0	11.7	15.2
E	13.2	12.9	16.4
F	14.5	14.2	17.7
G	17.5	17.1	20.6
H	21.1	20.7	24.2
I	25.7	25.1	28.6
J	31.2	30.5	34.0
K	37.8	36.9	40.4
L	45.8	44.7	48.2
M	55.4	54.1	57.6
N	67.2	65.6	69.1
O	81.4	79.5	83
P	98.6	96.3	100
Q	119.0	116	120
R	145.0	142	145
S	175.0	171	174
T	212.0	207	211
U	257.0	251	255
V	312.0	305	308
W	378.0	369	373

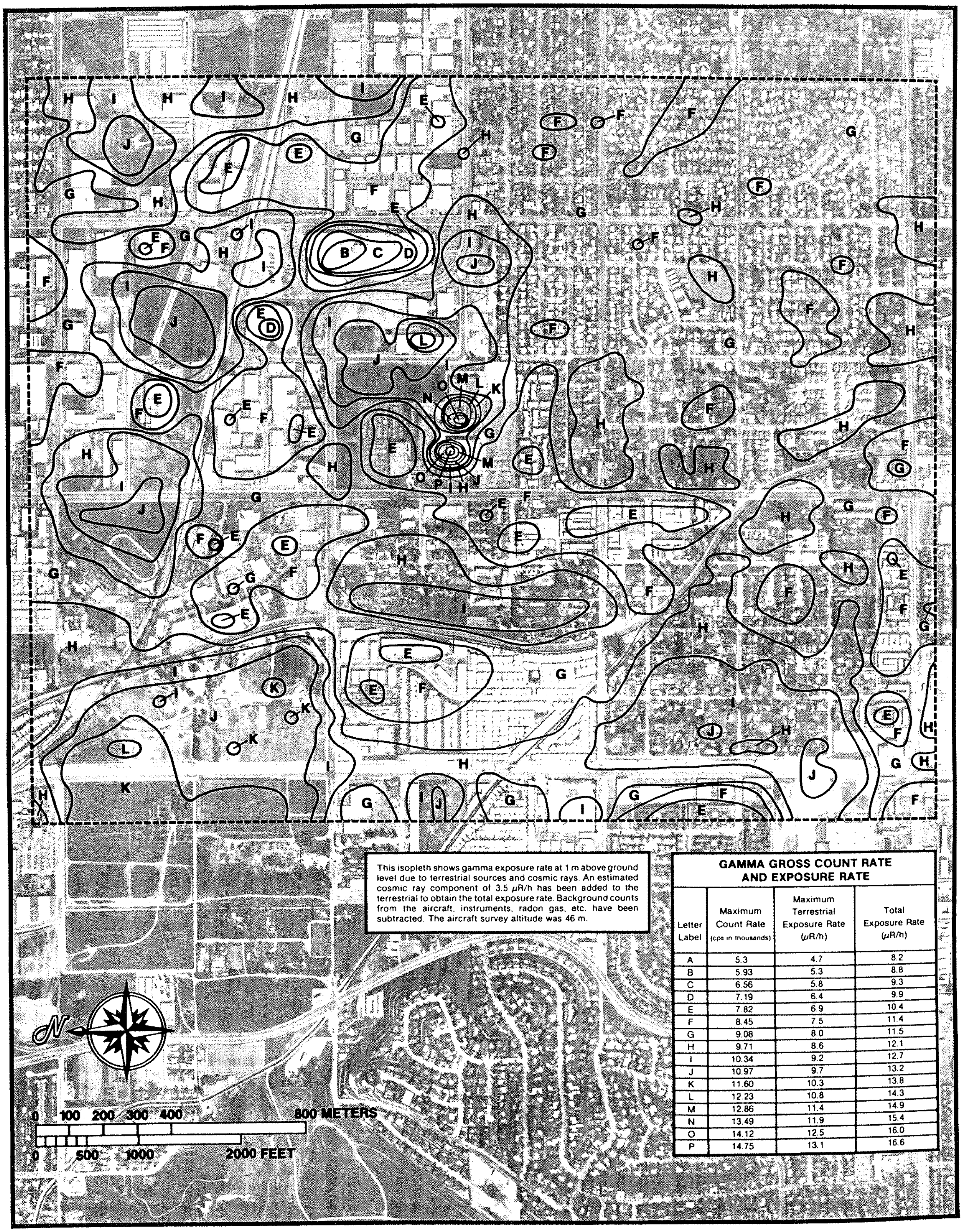
Before the gamma isopleths of either survey are considered, it should be noted that the remote sensing system in the H-500 helicopter is an uncollimated array of sodium iodide detectors. The inherent spatial resolution of such a system is one to two times the distance between the surveyed surface and the detectors. Frequently, ground surveys are performed with hand-held detectors at a distance of 1 m from the surface; if the survey area contains sources with lateral dimensions which are small in comparison to aircraft survey altitudes, the ground survey results will not compare with the aerial results. A ground survey of a point source will produce a distribution pattern with a radius of, perhaps, 1 m or 2 m; an aerial survey of the same source will yield a distribution pattern with a radius of several tens of meters. Hence, the results of in situ measurements at 1 m, or from soil samples, must be averaged over a large area for comparison with aerial isopleths. Ion chamber measurements and soil samples have been collected routinely on the sites of AMS aerial surveys. When properly averaged the results are consistently within 20% of exposure rates determined from the air.[5,6]

7.0 RESULTS

7.1 Canoga Park, DeSoto Facility

Figure 8 is a gamma gross count isopleth map of the Rockwell International DeSoto Facility in Canoga Park, California. Shown here is the exposure rate, in microroentgens per hour (μR/h), normalized to a distance of 1 m above ground. The exposures shown may result from naturally occurring or man-made gamma emitters which range in energy from 50 keV to 4.07 MeV. All the data shown were recorded in June 1978.

Bare ground or grassy areas without trees or buildings near the DeSoto Facility generally show a J or K level, which is apparently characteristic of the soil in the Canoga Park area. This corresponds to a terrestrial exposure rate of



This isopleth shows gamma exposure rate at 1 m above ground level due to terrestrial sources and cosmic rays. An estimated cosmic ray component of 3.5 μR/h has been added to the terrestrial to obtain the total exposure rate. Background counts from the aircraft, instruments, radon gas, etc. have been subtracted. The aircraft survey altitude was 46 m.

GAMMA GROSS COUNT RATE AND EXPOSURE RATE

Letter Label	Maximum Count Rate (cps in thousands)	Maximum Terrestrial Exposure Rate (μR/h)	Total Exposure Rate (μR/h)
A	5.3	4.7	8.2
B	5.93	5.3	8.8
C	6.56	5.8	9.3
D	7.19	6.4	9.9
E	7.82	6.9	10.4
F	8.45	7.5	11.4
G	9.08	8.0	11.5
H	9.71	8.6	12.1
I	10.34	9.2	12.7
J	10.97	9.7	13.2
K	11.60	10.3	13.8
L	12.23	10.8	14.3
M	12.86	11.4	14.9
N	13.49	11.9	15.4
O	14.12	12.5	16.0
P	14.75	13.1	16.6

Figure 8. *GROSS COUNT ISOPLETH MAP: CANOGA PARK*

approximately 10 μR/h. The terrestrial rates for several California cities are quoted for comparison: Romana (7.4 μR/h), San Diego (7.0 μR/h), Santa Maria (6.8 μR/h) and Bishop (14.9 μR/h).[4] The anomalous L value in the park-like area in the northwest corner of the survey area (85 m east of Canoga Avenue, 200 m north of Prairie Avenue) has no apparent correlation with man-made facilities in that area. It may simply represent a natural concentration of radioisotopes normally present in the soil. These concentration levels can vary strongly from one geographical area to another; even for a survey area as small as the present one, intensities measured over bare ground may vary considerably.

The Rockwell International Manufacturing and Development Building (Building 001) shows the highest activity on the isopleth map: Level P (16.0-16.6 μR/h). Enriched uranium fuel elements had been collected near the north end of Building 001. These were manufactured for a reactor at the Idaho National Engineering Laboratory. The survey was flown during a regularly scheduled truck loading operation.

Figure 9 shows a gamma radiation spectrum recorded during Flight Line 3 (Figure 3) which passed directly over the loading area. Normal background radiation, recorded on the same Flight Line but some distance from the DeSoto Facility, has been subtracted from the data shown. The spectrum shows two peaks; the lower one, at approximately 70 keV, is simply the lower end of the Compton continuum, which is sharply cut off at 50 keV. The upper peak is the prominent 186 keV photopeak of ^{235}U. The absence of other contributions implies that the strongest uranium peak clearly dominates all other photopeaks which may have been recorded. The measured activity level is approximately 21% higher than the surrounding background.

Two storage areas were overflown on Flight Line 5 (Figure 3); these were labeled Storage Yards 506 and 512. Because of their relatively small size the gross count isopleth map does not allow the reader to pinpoint the location of the source(s). The activity level 0 (15.4 - 16.0 μR/h) indicates that the stored material was, perhaps, 16% more radioactive than bare Canoga Park soil. Figure 10 is a spectrum taken from the portion of Line 5 covering the storage areas; it shows that the sources were of low level, and either well-shielded or well-distributed in photopeak distribution. That is, the spectrum shows no prominent photopeaks which would permit the author to identify their origin.

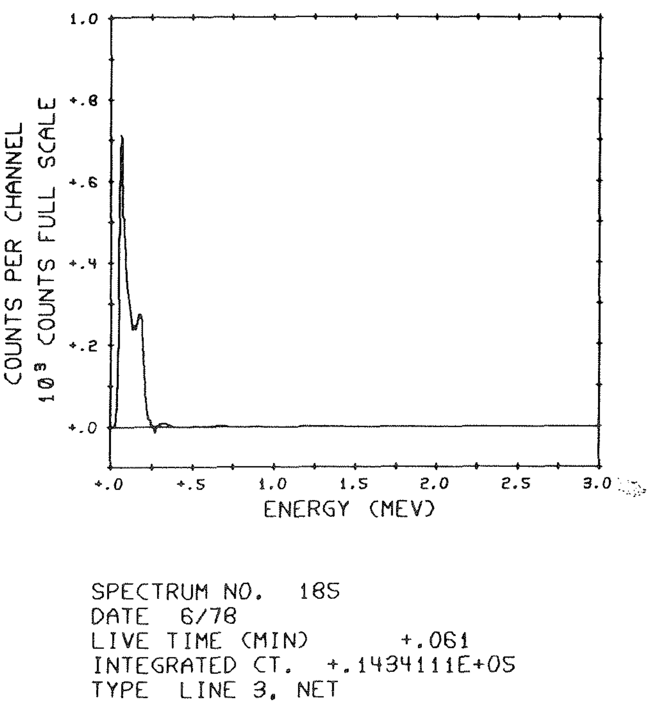


Figure 9. *GAMMA SPECTRUM: MANUFACTURING AND DEVELOPMENT BUILDING*

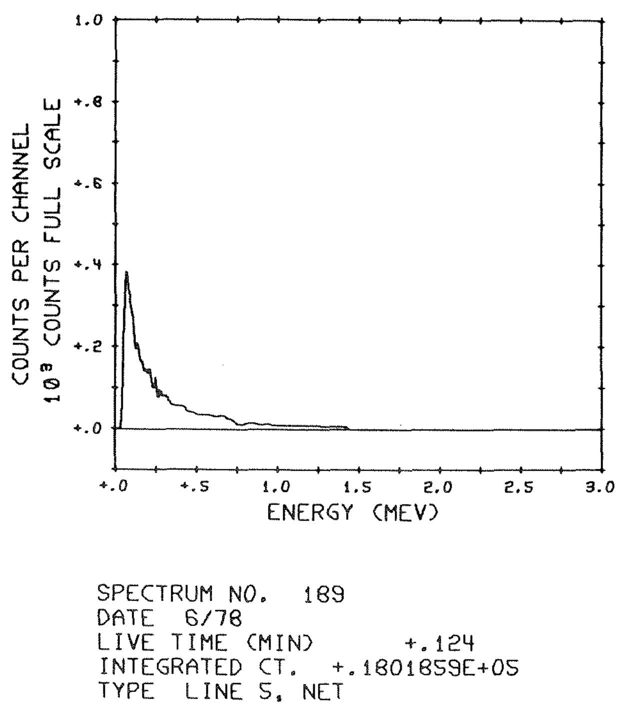


Figure 10. *GAMMA SPECTRUM: RADIOACTIVE WASTE STORAGE YARD*

Just east of Lurline Avenue and north of Bahama Street are the facilities of International Engine Parts, Inc. (IEP). This company is not on Rockwell property, nor is it affiliated with Rockwell. It is included in the survey simply because of its physical proximity. Line 10, which passed directly over IEP, showed slightly enhanced activity: level L (13.8 - 14.3 μR/h).

Aircraft engines stored within the building enhance the activity level by approximately 4%. Subsequent investigation showed that thorium was the isotope responsible: a thorium-magnesium alloy is used in the forward compressor case of the General Electric J-79 jet engine, which is conventionally used as the power plant in F-104 and F-4 jet aircraft.[7]

Figure 11 shows a gamma spectrum obtained as the aircraft passed over IEP on Line 10. The observed activity is extremely low; poor counting statistics preclude an attempt to identify the source from its spectrum. A thorium source of even greater intensity would be difficult to identify because of the shielding provided by the building roof. Natural background has again been subtracted from the data shown.

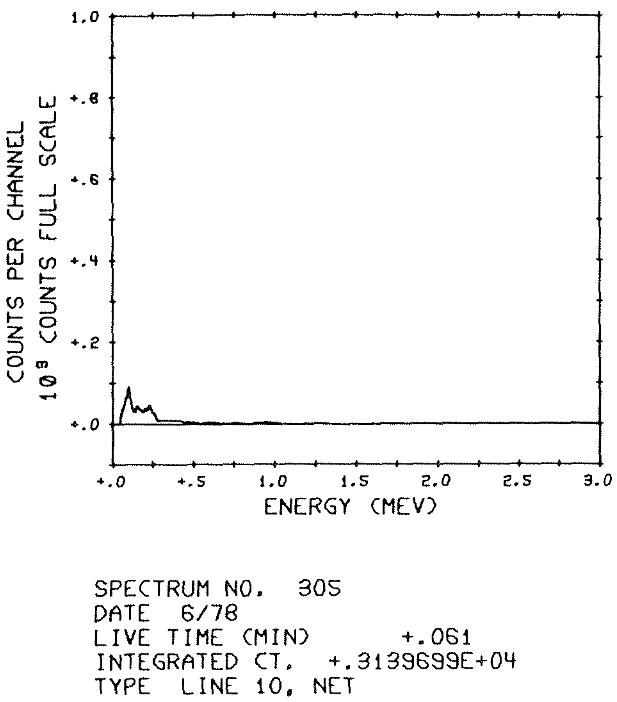


Figure 11. *GAMMA SPECTRUM: INTERNATIONAL ENGINE PARTS, INC.*

A high density of buildings, either residential or commercial, generally changes the exposure rate measurements obtained during an aerial survey. Common construction materials used near the Rockwell facilities, and in most areas of the country, are less radioactive than the ground they cover.

Southwest of Rockwell International the dense concentration of homes and apartments drops the activity level to a G, a reduction of approximately 17%. Some clusters of homes, characterized by roofs of a unique reddish-brown color, apparently have even less activity, since they drop the measured level to F, 21% below normal soil background levels. One such cluster is bounded on the north, east, south, and west by Chase Street, Independence Avenue, Community Street, and Variel Avenue, respectively. A second cluster is bounded by Bryant Street, Lurline Avenue, Chase Street, and Kelvin Avenue, respectively

This same effect would be produced if the F-level buildings are taller than their neighbors, but built of the same materials. A mass of low activity material shields more or less of the ground surface, depending on its proximity to the aircraft.

Raw count rate data can be corrected for altitude variations; i.e., the count rate is inversely related to the distance between the survey subject and the aircraft. This was not done at Canoga Park, however, because the high density of construction in the survey area causes many sharp pulses on the radar altimeter. Because of the survey speed, these readings are not sufficiently accurate to use for count rate corrections.

These homes with reddish-brown roofs are not unique; other homes in the area also have the same effect on intensity levels. For example, the apartment complex just south of the Rockwell facilities (bounded on the north by an extension of Gresham Street, the east by Lurline Avenue, the south by Londelius Street, the west by DeSoto Avenue) drops the intensity to F or even E level. The effect is dramatic for many large buildings within the survey area, including the Rockwell Engineering and Administration Building (Building 002). The strongest example of this effect is the drop to a B level over the large building just east of the jog in Nordhoff Street. This is a 37% drop in measured activity level.

Small plots of bare ground or grass, such as the Rockwell property along Nordhoff Street and Lurline Avenue, tend to be affected by the land use and radiation intensities of surrounding property. Bare Rockwell land shows levels lower than J in places because of nearby parking lots and buildings which cover the more active native soil.

There are apparent differences in the inherent activity of some paving materials, however. A large paved area northwest of the intersection of Chase Street and Sunny Brae Avenue increases the intensity to H, from the G level of surrounding homes. It is also apparent that tall trees cause a slight increase in activity, as compared to the homes they surround. Trees bounded by Londelius, Lurline, Bryant, and DeSoto show this phenomenon. Perhaps more bare ground can be seen in these areas. Trees could cause this by lifting radioactive constituents of the soil, such as ^{40}K, closer to the aircraft.

From the foregoing comments based on the aerial survey of 27 June 1978 (Figure 9), it appears that the use of radioactive materials at the De Soto Facility of Rockwell International has no measurable impact on the surrounding community. Even at the survey altitude of 46 m (150 ft), activity on Rockwell property cannot be measured from the property boundary lines.

7.2 Santa Susana Field Laboratories

Figure 12 is the gamma gross count isopleth map for the Santa Susana Field Laboratories which are operated by Rockwell International for the U.S. Department of Energy. The survey was flown on 29-30 June and 5-8 July. As on the previous isopleth map, gamma rays of an extremely broad energy range are shown: 50 keV to 4.070 MeV. The map shows that radioactive materials appear to be concentrated in three areas at Santa Susana. It must be remembered, however, that high level activity tends to obscure nearby sources of low activity. Hence, the significance, or even the very existence, of weak sources tends to be lost when sites of this type are mapped. An altitude correction factor was applied in the preparation of this isopleth map. That is, all count rates were normalized to the survey altitude of 61 m (200 ft). Also, as in the previous isopleth (Figure 9), a 3-second, sliding interval average was applied to all survey data points before they were plotted. This minimizes statistical anomalies and effectively provides a smooth, two-dimensional display.

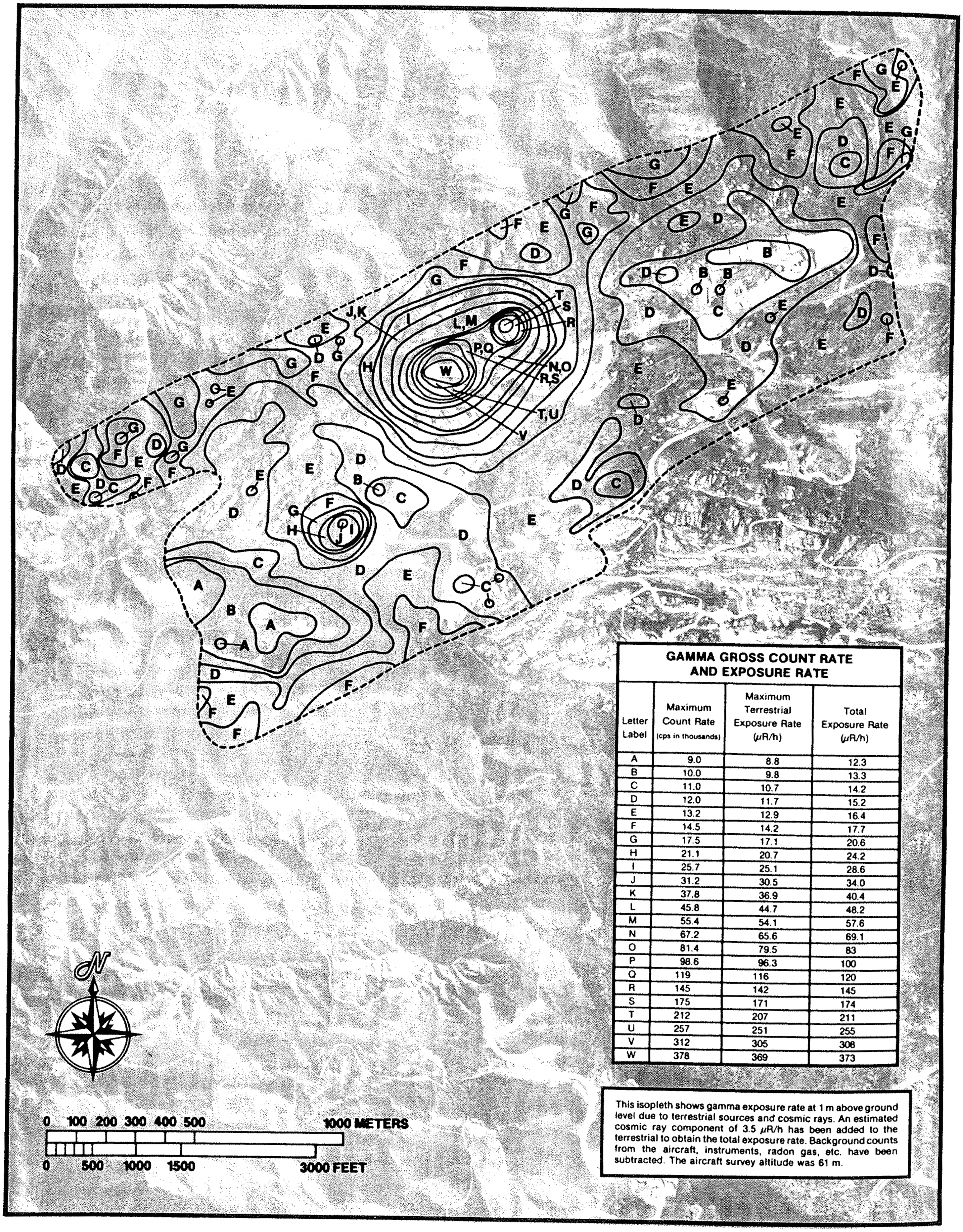
The weakest source shown is apparently centered at the north end of Building 20, the Atomics International Hot Laboratory. Informed sources at the site indicated that fuel decladding operations were being conducted in the Laboratory.[8] The exposure rate observed (J=28.6 - 34.0 μR/h) is approximately twice the normal background rate in the surrounding Santa Susana Mountains: E=15.2 - 16.4 μR/h.

Since single sources tend to generate circular isopleth patterns, the distortion in the Building 20 contour suggests that less active materials may be stored in the south end of the Laboratory. Similarly, some materials may be stored at Building 9, the Engineering Development Facility, or at Building 100, the Advanced Fuels Laboratory. If such materials are present, they appear to be of low activity or to be well-shielded.

Figure 13 is a gamma spectrum recorded over the Hot Laboratory. Cesium-137 and cobalt-60 are readily recognizable. Tantalum-182 is known to be present in the area; it may contribute to the other observed photopeaks at 803-, 923-, 1083-, and 1456-keV. The shape of these peaks suggests that many other sources may be contributing. Fission products and activation products are anticipated in stainless steel. Only long-lived isotopes should be prominent because the system being dismantled had already undergone 13-14 years of decay.

An even stronger source, with an exposure rate of T=174-211 μR/h, appears to be centered on the northwest corner of Building 143, the Sodium Reactor Experiment (SRE). The size of the source distribution suggests that multiple sources contribute to the pattern. Indeed, a personal inspection of the facility showed that many tons of radioactive materials were stored in boxes to the north and west of Building 143. From the present data it is not possible to determine whether materials in the yard or in the SRE are principally responsible for the high intensity of the source. The activity level is approximately 12 times higher than background. Figure 14 is a gamma spectrum recorded over SRE. Although many isotopes contribute, only ^{137}Cs and ^{60}Co isotopes can be readily identified.

The L-85 reactor in Building 93 apparently makes no appreciable contribution to the activity levels in the vicinity, although it is in close proximity to



GAMMA GROSS COUNT RATE AND EXPOSURE RATE

Letter Label	Maximum Count Rate (cps in thousands)	Maximum Terrestrial Exposure Rate (μR/h)	Total Exposure Rate (μR/h)
A	9.0	8.8	12.3
B	10.0	9.8	13.3
C	11.0	10.7	14.2
D	12.0	11.7	15.2
E	13.2	12.9	16.4
F	14.5	14.2	17.7
G	17.5	17.1	20.6
H	21.1	20.7	24.2
I	25.7	25.1	28.6
J	31.2	30.5	34.0
K	37.8	36.9	40.4
L	45.8	44.7	48.2
M	55.4	54.1	57.6
N	67.2	65.6	69.1
O	81.4	79.5	83
P	98.6	96.3	100
Q	119	116	120
R	145	142	145
S	175	171	174
T	212	207	211
U	257	251	255
V	312	305	308
W	378	369	373

This isopleth shows gamma exposure rate at 1 m above ground level due to terrestrial sources and cosmic rays. An estimated cosmic ray component of 3.5 μR/h has been added to the terrestrial to obtain the total exposure rate. Background counts from the aircraft, instruments, radon gas, etc. have been subtracted. The aircraft survey altitude was 61 m.

Figure 12. *GROSS COUNT ISOPLETH MAP: SANTA SUSANA*

COUNTS PER CHANNEL

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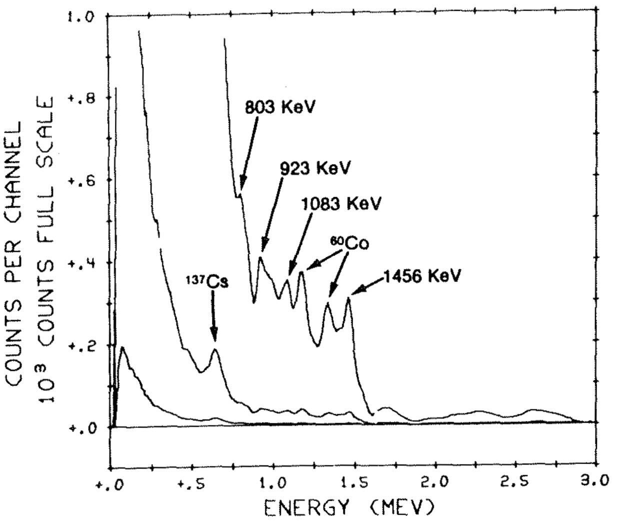
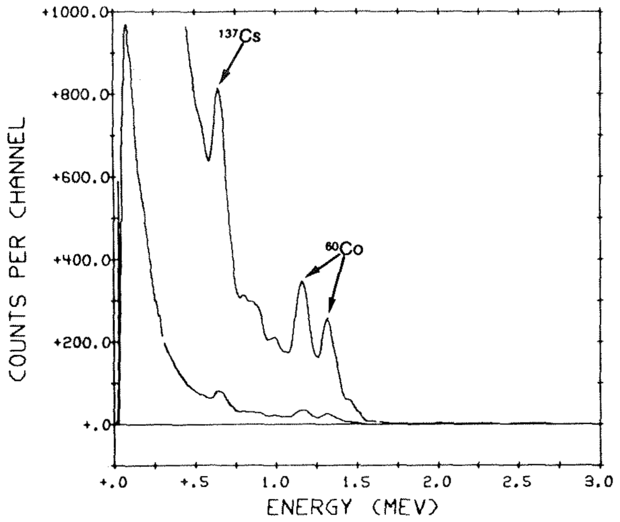
vessel



SPECTRUM NO. 175(22,23)
DATE 7/7/78-2
LIVE TIME (MIN) +.132
INTEGRATED CT. +.1035300E+05
TYPE L=2, SANTA SUSANA, HS#2, GROSS
ALTITUDE 200 FT.
AIRCRAFT H-500

Figure 13. *GAMMA SPECTRUM: ATOMICS INTERNATIONAL HOT LABORATORY*



SPECTRUM NO. 161(15,16)
DATE 7/7/78-2
LIVE TIME (MIN) +.127
INTEGRATED CT. +.5203300E+05
TYPE L=-5, SANTA SUSANA, HS#2 GROSS
ALTITUDE 200 FT.
AIRCRAFT H-500

Figure 14. *GAMMA SPECTRUM: SODIUM REACTOR EXPERIMENT (SRE)*

the activity in Building 143. The contours surrounding Building 143 are unperturbed by L-85.

The most intense activity at Santa Susana is centered on Building 621, the Radioactive Accountable Waste Storage Building, and other buildings or containers near it. Building 75, the Contaminated Equipment Storage Building, was reported to contain low level waste. Just east of Building 621 was a tank which supposedly contained $5x10^3$ gallons of radioactive liquid. Building 22, the Radioactive Waste Storage Vault Building, reportedly contained considerable numbers of reactor fuel elements in underground storage. Directly north of Building 22 is a leach field where liquid radioactive wastes were dumped. Because of the high level of activity centered on Building 621 and contiguous buildings or containers, it is impossible to determine from the present data whether the leach field itself makes a measurable contribution to the radiation levels in the area. The maximum activity level for this region is about 20 times the local background. No comment can be made regarding the reported presence of a reactor core vessel in Building 59, the Large Leak Test Rig. Building 59 appears to be in an area characterized by local background readings.

Figure 15 is a gamma spectrum recorded over the Radioactive Accountable Waste Storage Building (Building 621). As in the previous spectrum ^{137}Cs and ^{60}Co dominate so strongly that other isotopes are completely masked.

Because of the high intensity levels of the sources described above, a special flight over Santa Susana was conducted on 7 July 1978. The REDAR system sensitivity was reduced considerably: data were accumulated with only one of the 20 NaI detectors. During this flight, which took place between 1:58 p.m. and 3:15 p.m., a fourth very intense source was also discovered while flying over Buildings 171 and 172, which are x-ray facilities. These sources are not shown on the map because they were of very short duration and occurred on only two survey lines directly over these buildings.

The resultant x-ray isopleth contours were long and narrow, very different from the circular signatures of the other sources at the site. To verify that these intense signals were due to intermittent X rays, the author checked the operating schedule with x-ray personnel. Some 30 X rays were taken during the course of the afternoon. Apparently some of these coincided with helicopter overflights. The spectrum of these signals is quite characteristic of x-ray sources (Figure 16).

It is also known that radioactive materials were moved between facilities while survey work was in progress. Attempts were made to avoid flying over such sources. From the comments of informed site personnel, it would appear that all the isopleth contours shown in Figure 12 can be attributed to known, fixed sources.

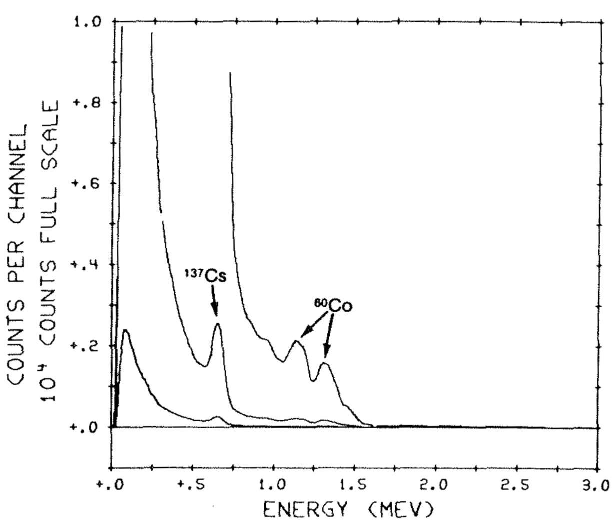
Several helicopter flights were also made along stream drainage paths from the Santa Susana site. No evidence of stream-borne contamination was observed.

8.0 CONCLUSION

Two aerial radiological surveys were performed of facilities operated by Rockwell Internatonal. They were conducted from a United States Department of Energy helicopter equipped with 20 sodium iodide detectors, a multichannel analyzer, and a magnetic tape recording system. At the DeSoto Facility in Canoga Park, surveyed on 27 June 1978, two low-level radiation sources were discovered: enriched ^{235}U fuel elements being shipped from the Manufacturing and Development Building (Building 001) and low-level materials in storage yards 506 and 512, just east of Building 001. Both sources show exposure rates approximately 20% higher than surrounding background. Neither source could be detected at DeSoto property lines from the survey altitude of 46 m.

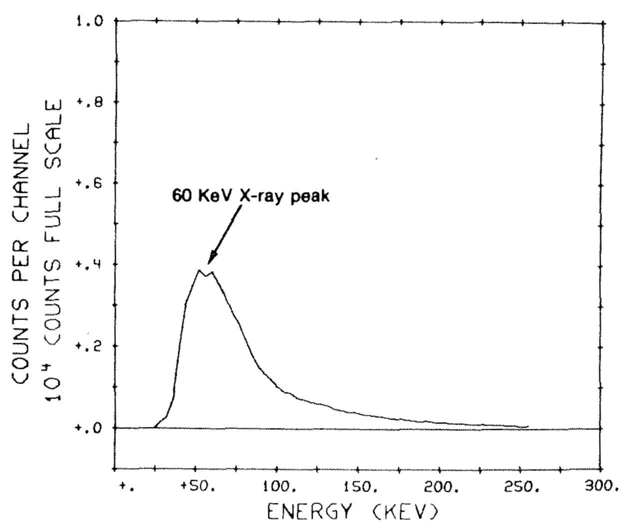
Three considerably stronger sources were located at the Santa Susana Field Laboratories, which are approximately 15 km west of the De Soto Facility. This survey was conducted on 29-30 June and 5-8 July.

The north end of Building 20, the Atomics International Hot Laboratory, shows an exposure rate twice that of normal background. The northwest corner of Building 143, the Sodium Reactor Experiment, has an activity level approximately 12 times background. Building 621, the Radioactive Accountable Waste Storage



SPECTRUM NO. 161(13,14)
DATE 7/7/78-2
LIVE TIME (MIN) +.120
INTEGRATED CT. +.1226800E+06
TYPE L=-5, SANTA SUSANA, HS#1, GROSS
ALTITUDE 200 FT.
AIRCRAFT H-500

Figure 15. *GAMMA SPECTRUM: RADIOACTIVE ACCOUNTABLE WASTE STORAGE BUILDING*



SPECTRUM NO. 175(16,21)
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LIVE TIME (MIN) +.375
INTEGRATED CT. +.2176142E+06
TYPE L=2, SANTA SUSANA, HS#1, GROSS
ALTITUDE 200 FT.
AIRCRAFT H-500

Figure 16. *GAMMA SPECTRUM: X-RAY SOURCES IN BUILDINGS 171 and 172.*

Building, shows a rate 20 times background. All three sources may obscure many low level sources in close proximity to the primary sources. Intermittent x–ray signals were also detected over Buildings 171 and 172, which are x-ray laboratories in active use during the aerial survey. The Santa Susana survey altitude was 61 m. No gamma emission above background levels was detected in normal drainage channels from the survey area.

APPENDIX*

Microwave Ranging System and Steering Indicator/Calculator

A line-of-sight, X-band microwave system, comprised of a master (aircraft) and two remote (ground) stations, is used to determine the distance of the aircraft from the ground stations. Each of the three transceiver units provides an output of up to one kilowatt peak power. The system is capable of measuring ranges up to 100 nautical miles under line-of-sight conditions. Resolution of the system is one foot, and accuracy is better than ± 10 feet. Transmissions are coded to differentiate between the two ground-based transponders. Signals from the transponders are at a frequency different from the master's in order to guard against ranging from the master to microwave-reflecting objects.

A control unit in the aircraft initiates a complete interrogation cycle every 250 milliseconds. This cycle consists of a group of pulses to establish which of the two transponders is being interrogated, followed by ranging pulses (up to forty) until ten valid returns have been received. The control unit then outputs the average measured range to external equipment. If ten valid returns are not received, the control unit will output a "zero-range" to the external equipment. The procedure is repeated for the second transponder. To acquire, the two ranges may take from 45 milliseconds to 140 milliseconds. The microwave system idles for the remainder of the 250 millisecond cycle.

External Equipment Use of MRS Ranges

External equipment receiving range data from the control unit are the Radiation Data Acquisition and Recorder system (REDAR) and the Steering Indicator Calculator (SIC). A range pair is recorded on the REDAR tape along with the concurrent radiation data for each 1 second of data acquisition. The processing of REDAR tape recorded ranges is described elsewhere. The steering indicator/calculator reads in a range pair every quarter-second. These data are processed in real time to give the aircraft pilot an on-line or quantitative left- or right-of-line indication.

* Written by A.E. Villaire. May 1979. Las Vegas, NV: EG&G.

Steering Indicator Calculator System

The heart of this system is a programmable desk-top calculator which weighs only 25 pounds (Hewlett-Packard 9825A). It is programmable in a high level language (similar to FORTRAN) and has about 6800 bytes of user memory for program and data storage. The unit also contains a drive mechanism for magnetic tape cartridges, a small thermal printer, and a 32-character display. The use of a high level language facilitates modification of the calculator program to fit unique field situations.

A special interface circuit effects compatibility between the MRS's 24 data output lines and 2 strobes with the calculator's 16 byte input data buss, control, and status lines. Also provided in this circuit is a digital-to-analog converter to drive the pilot's steering meter. The interface is under the direct control of the calculator program.

Calculator Program

Arithmetic calculations, using the actively measured ranges, are performed by the calculator to do the following:

- Measure the distance between the two ground stations (the "baseline" length).
- Translate and rotate the desired survey grid from the orthogonal system of the baseline to an orthogonal system centered on two observable terrain features.
- Provide the pilot with left/right steering information.
- Provide the SIC operator with information on line number, direction of flight, steering error, in or out of survey area, distance to end (or beginning) of line, and ground speed.

Operational Sequence

The relative location of the survey area with respect to the baseline (i.e., "above" or "below") must first be keyed into the calculator in order to remove the positional (bipartite) ambiguity caused by the MRS giving only two ranges and no angular information.

Prior to the start of the actual survey certain flight maneuvers are required to measure parameters.

- Baseline measurement: the distance between the ground-based transponders is measured by flying across the baseline (preferably mid-way) at as low an altitude as is practical. The value calculated for the baseline length is the minimum of the sum of the two ranges.

- Survey orientation and location: the aircraft crew must find two terrain features, natural or man-made, that can also be found on the map or aerial photo depicting the survey lines. Instantaneous ranges measured while passing directly over these features are entered in the calculator memory using a "hack" button. The two range pairs obtained are used by the program to calculate the angle between the baseline and the survey lines and the offset of the survey area from the baseline. If the two hack points do not lie on a line parallel to the desired survey lines, an angular correction may be manually entered in the calculator. The operator must then key in the intended survey line spacing; he may also enter values representing the longitudinal extent of the lines. The latter option is sometimes not used for extremely long lines where loss of reliable signal determines the ends of the lines. All these data are printed out and are recorded on tape so they may be recalled for use at another time.

The survey then proceeds with the operator keying in the initial line number and direction of flight (handled simply as "+" or "-"). At the end of a line, the operator increments or decrements the line number and reverses the sign of the flight direction. The pilot, after negotiating a turn, may use the steering meter to "home in" on the new line. The operator may relay to the pilot the distance to the start of the line (if the longitudinal extent values were keyed in) so that no harsh maneuvers are required in order to start the next line. (Even moderate aircraft banking causes loss of microwave signal as the fuselage or wings occlude the line of sight).

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